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# A STUDY OF THE BIOLOGICAL IMPACT OF THE HELENA SEWAGE TREATMENT PLANT DISCHARGE ON PRICKLY PEAR CREEK

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Prepared by:

GARY L. INGMAN
JANUARY 1978
WATER QUALITY BUREAU
MONTANA DEPARTMENT OF HEALTH
AND ENVIRONMENTAL SCIENCES

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I. Introduction

Prickly Pear Creek originates some 20 miles to the southeast of Helena along the west slopes of the Elkhorn Mountains. The mouth of the creek, originally on the Missouri River above the present site of Hauser Dam, is now located at Lake Helena, a flooded arm of Hauser Lake created by the dam. Much of the stream's headwater region and tributaries have been impacted by extensive placer and hardrock mining operations which continued into the 1940's (Pedersen, Boulder Batholith Study, WQB, 1977). However, a great deal of natural restoration has occurred, and immediately above East Helena, the stream supports a diverse invertebrate association and a healthy trout fishery (personal communication and experience). From East Helena upstream, the creek is classified B-D1 in the Montana Water Quality Standards (Montana Water Quality Standards). The section from below East Helena to the mouth is markedly different. Invertebrate associations show substantial impact and salmonid fishes are scarce. This stretch is classified E-$F_1$. Excluding irrigation return water and a limited seasonal outfall from East Helena's sewage lagoon, the only discharge to the stream in this area is the Helena Sewage Treatment Plant (STP) effluent. The effluent, after receiving secondary treatment, flows eastward from the plant in a ditch for roughly a mile before entering Prickly Pear Creek at a point about 4 miles upstream of the mouth. It was the purpose of this study to examine the biological impact of this discharge on Prickly Pear Creek.

## II. Methods

This study was undertaken in June and July of 1977. The following stations were chosen for sampling:

Site 01 - Prickly Pear Creek 100 yards above the sewage discharge

Site 02 - The sewage discharge (Partial*)

Site 03 - Prickly Pear Creek 100 yards below the discharge

Site 04 - Prickly Pear Creek 2.5 stream miles below the discharge at Mountain View School

Degree of impact was determined by examining quantitative and qualitative macroinvertebrate samples and qualitative periphyton samples and by measuring biomass and chlorophyll accrual rates on artificial substrates. Water samples were also collected, but exceeded maximum holding times in the lab and results of nutrient analyses had to be discounted. Temperatures and flows were measured.

a) Chlorophyll and biomass analysis:

Artificial substrates consisting of a plastic rack containing 8 microscope slides were exposed at 3 of the 4 sample sites for periods ranging from 7 to 26 days. Substrates were not placed in the sewage ditch (02) because of a lack of flow (see Section III) and accurate comparisons of productivity cannot be made between stagnant and flowing water by this method. Determinations were made for total and per-day accrual of biomass and chlorophylls a, b, and c. Per-day accrual rates of biomass and chlorophyll a are useful as estimates of net primary productivity and total accrual for the exposure period can be used in calculation of an autotrophic index (AI). This index is a valuable tool for determining what proportions of the periphyton community are represented by

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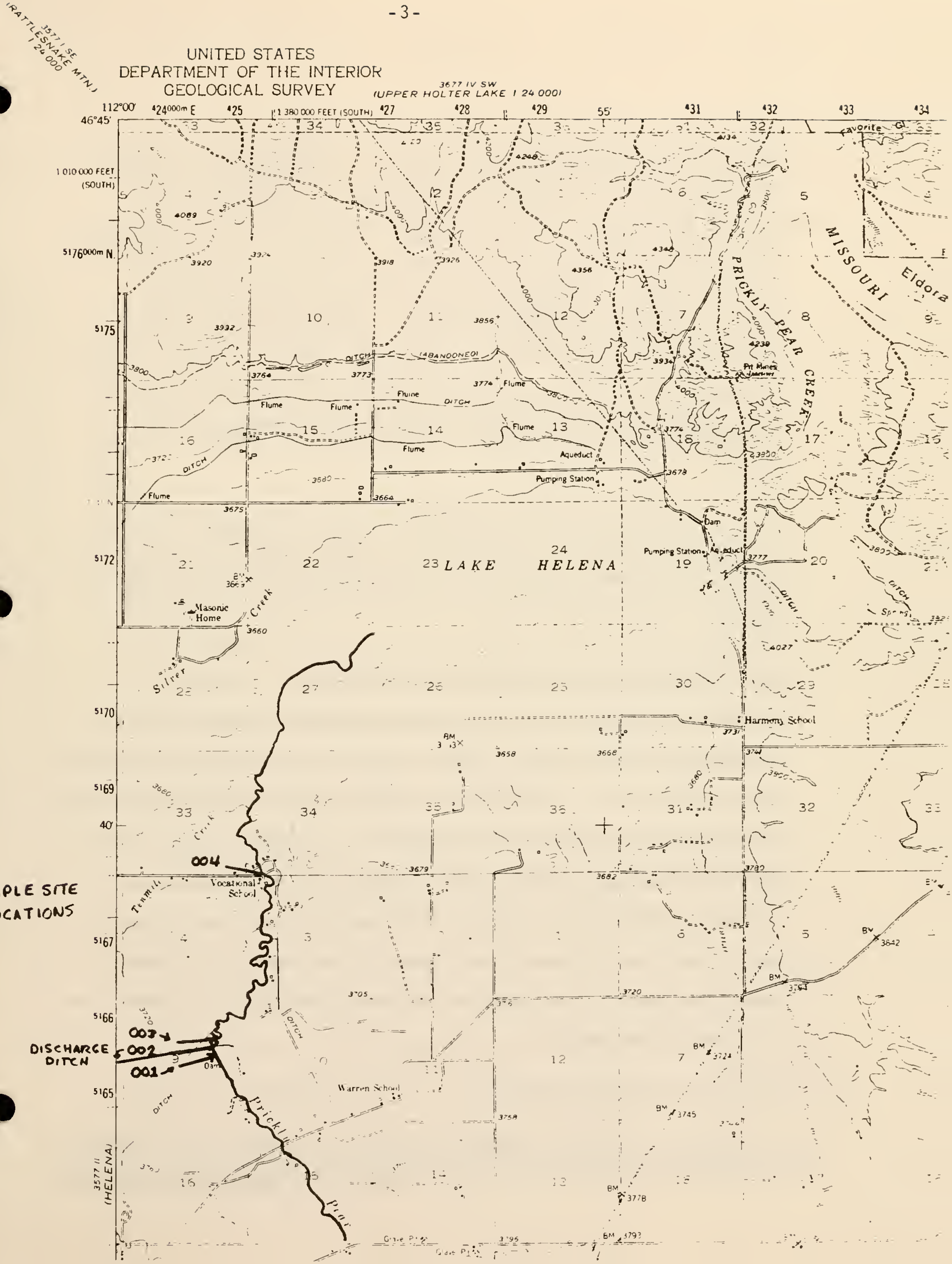
*see Sections II(a),(b), III(a)




SAMPLE SITE LOCATIONS

heterotrophic organisms (those requiring preformed organic molecules for subsistence) and what fraction consists of autotrophic (photosynthetic) organisms. A high AI value is generally a good indication of some degree of organic pollution, which may be contributed by municipal sewage. Although difficult to quantify precisely, pure algal cultures will yield AI's ranging from roughly 40 to 100. Values of 150 to 200 indicate some degree of organic pollution and values of 200 and up, moderate to severe pollution (Standard Methods, 14th ed., 1975).

Lab and field procedures were the same as those outlined by EPA (EPA, 1973) raw data and explanation of calculations are included in the appendix.

b) Aquatic Macroinvertebrate sampling and analysis

Assessments of aquatic macroinvertebrate associations were made at all sites except the actual STP discharge ditch (02). Flow was non-existent here (see Section II), confounding efforts to collect benthic organisms. Qualitative and quantitative estimates were determined from 3 square-foot Surber bottom samples at each site. Specimens were preserved in 90% ethanol and identified to genus (where possible) at the Water Quality Bureau in Helena. Shannon-Weaver diversity and equitability values were calculated for each sample. Raw data, formulas, and rationale are included in the appendix.

c) Periphyton sampling and analysis

Qualitative periphyton samples were taken at all sites, including the actual sewage ditch (02). The method involved scraping stones collected

from the stream bottom with a razor blade and depositing the material in a water-filled jar. Lugols Solution (IKI) was added as a preservative. Identifications were made of the algae and diatoms at the Water Quality Bureau and relative abundances determined. Shannon-Weaver diversity and equitability values were determined for diatoms only because of difficulties involved in identifying non-diatom algae to species and in counting filamentous algae. More detailed periphyton data are included in the results section and in the appendix.

## III. Results

a) Site description and macroinvertebrate sample analysis

Site 01: Physical habitat in Prickly Pear Creek just above the Helena STP discharge consists of a shallow riffle with a substrate of small cobbles and fine sand. Banks appear to be fairly stable, but streamside vegetation is restricted to grasses and small shrubs. About 50 yards upstream, larger shrubbery and small trees dominate the streamside but riffles are absent, being replaced by deeper pools. The bottom is almost entirely sand. Most invertebrates collected just above the discharge are intolerant to organic pollution or facultative* (EPA, 1973). Tolerant forms are scarce. The Shannon-Weaver diversity index ($\bar{d}$) is 3.09 for this site (Shannon, Weaver, 1949). It is generally assumed that a value between 3 and 4 indicates clean streams (EPA, 1973). Equitability (e), an index of "evenness" of distribution of individuals among the taxa found, equals 1.0. Under "normal" circumstances, this is the maximum obtainable theoretical value.

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*"Having a wide tolerance range and frequently associated with moderate levels of organic pollution."

Values greater than 1 may occur when sample size is very small and the few organisms collected are represented by only several taxa (EPA, 1973). Pollution in one form or another alters the distribution of numbers of organisms present in each species group by allowing tolerant species to thrive while less tolerant species decline. The resulting change in numbers distribution will give an "e" value considerably less than 1.

The density of invertebrates at this site is low compared to other streams of similar trophic status (containing similar levels of nutrients, especially nitrogen and phosphorus) (Biological Monitoring Program Data, WQB, 1977). Although not accurately documented, this section of Prickly Pear Creek probably suffers from dewatering in late summer (personal communication, local residents). Depression in the aquatic invertebrate association due to the resultant high temperatures and depressed dissolved oxygen levels is a possibility. If this is the case, invertebrates must be replaced or at least replenished annually by downstream drift. Temperatures recorded during the sampling period reached a peak of 72$^{\circ}$F on June 8 and stream flow dwindled to 10 cfs, a fourth of that measured two weeks earlier. These seasonal fluctuations could cause the low density of invertebrates.

It should be mentioned that, according to EPA (EPA, 1973), $\bar{d}$ and "e" values computed from a sample size of less than 100 should be examined with caution.

Only 30 invertebrates were collected in three square-foot bottom samples at this site. But the presence of mostly intolerant and facultative

species indicates that this section of the creek was not suffering from gross organic pollution levels during the period of study.

Site 02: During the study period, nearly all of the STP effluent was being utilized for irrigation purposes and the actual discharge to Prickly Pear Creek was negligible. The lack of flow at the mouth of the ditch, as stated earlier, necessitated only partial sampling at this site. However, a cursory examination of habitat and invertebrates was carried out. The substrate of the ditch was composed of a thick sludge deposit which continually emitted bubbles to the surface, evidence of anaerobic decomposition. Invertebrates present at the site were restricted to dipteran larvae and some aquatic beetles. Most of the former were blackfly, midge, and mosquito larvae and were extremely abundant. Temperatures of the stagnant water were consistently higher than Prickly Pear Creek at the 3 other stations.

Site 03: The physical habitat available for a healthy invertebrate association directly below the STP ditch is marginal, at best. The stream bottom in this region is almost entirely coarse sand underlain with anaerobic muck. Riffles are absent. Vegetation along the banks is primarily small bushes such as wild rose. Larger trees and shrubs are mostly absent and it is evident that much vegetation of this type has been removed from the margins of the stream channel. Stream banks are very unstable and erosion is a definite problem. Evidence includes cutoff meanders and piles of sand with partially buried garbage 20 to 30 feet from the present channel. There is an abandoned irrigation headgate and dam about 50 yards below the STP discharge. The creek drops 3 to 4 feet over the dam into a deep pool and is highly aerated. Flow and temperature fluctuations for this area are similar to those at the upstream site (01).

Invertebrate taxa collected from this location are nearly equally distributed among the three sensitivity classes--tolerant, facultative, and intolerant. The latter two classes, however, contain greater numbers of individuals. Many of the taxa represented at this site have high dissolved oxygen requirements. It must be remembered that no significant discharge to the creek occurred during sampling due to prior irrigation usage of the STP outfall. The presence of masses of sewage bacteria (Sphaerotilus) and sludge-feeding dipterans at this site indicate that a major discharge had recently occurred. Many of the taxa present may have drifted into the area and become established after the STP outfall was diverted for irrigation. Downstream drift of invertebrates is a continual process and a relatively short period of time is required to drastically affect community structure in an altered environment. A longer time is required before species interactions result in a stable climax community. Had a major discharge been occurring at the time of the sampling, a very different distribution of numbers and kinds of invertebrates may have resulted.

Total number of organisms is nearly double that of Site 001, although number of kinds (taxa) is slightly less. This is what one would expect. Addition of organic nutrients has been shown to increase the standing crop of invertebrates and decrease the number of taxa. The STP did not contribute a significant amount of nutrients during the study. But there was a significant accumulation of sludge which may have caused the increased productivity. The Shannon-Weaver index

value for this site is 2.94. This figure indicates only slight pollution. Equitability (e) for this site is, like Site 001, the maximum theoretical value, 1.0, indicating clean water. Again, it should be mentioned that total sample size is less than 100, and thus a great deal of reliance cannot be placed on the $\bar{d}$ and e values. Invertebrate standing crop is greater at this site, but all other indications are that the stream at the time of sampling remained relatively free of organic wastes, due to the lack of an active discharge.

Site 04: Of the three sites sampled for invertebrates, Site 004 contains the most suitable habitat. Riffles are present and the substrate is composed of small cobbles. Erosion probably poses a slight problem during runoff, and since the study period, the banks have been riprapped. Temperatures recorded here are similar to the upstream sites, but flows varied much less.

All of the species from this site whose sensitivities have been determined are intolerant to organic pollution. Again, many of these taxa have high dissolved oxygen requirements. However, diversity ($\bar{d}$) is 2.4. This value is somewhat less than the two upstream sites and indicates a slight amount of organic pollution. Equitability is .8, also less than the two upstream sites, but still indicating a healthy stream. Number of taxa at this site is the lowest of the three sites, but total number of individuals is nearly twice that of Site 003 and two-and-a-half times greater than Site 001. The invertebrate association at this site is affected more by sewage than at the other two sites. This probably results from the degradation of the raw sewage into less complex, more biologically available compounds during its 2.5 mile trip from the STP

outfall to the Mountain View site. Enrichment is thus greater. Increased standing crop of autotrophic biomass, produced in the stream during sewage discharge, might continue to support elevated populations of invertebrate grazers for some time after termination of these nutrient additions. Only repetitive sampling would depict trends.

b) Chlorophyll and Biomass

The following is a comparison of chlorophyll and biomass analysis results for the three stations from which data were obtained. Figures are averages determined from 2 to 14 replicate analyses. Additional data were available for the Mountain View station (04) from another study (Unpublished data, WQB, 1977), and the values were included in the averages for that site.

| STATION | PARAMETER | TOTAL ACCRUAL ($mg/M^2$) | ACCRUAL/DAY ($mg/M^2$/day) | NO. DAYS ACCRUAL |
|---|---|---|---|---|
| <u>01-Above the discharge</u> | | | | |
| | Chlorophyll <u>a</u>: | 53.3 | 4.1 | 13 |
| | Chlorophyll <u>b</u>: | 8.4 | .7 | 13 |
| | Chlorophyll <u>c</u>: | 12.4 | 1.0 | 13 |
| | Biomass: | 8775 | 675 | 13 |
| <u>03-Below the discharge</u> | | | | |
| | Chlorophyll <u>a</u>: | 27.5 | 2.3 | 12 |
| | Chlorophyll <u>b</u>: | 5.0 | .4 | 12 |
| | Chlorophyll <u>c</u>: | 8.0 | .7 | 12 |
| | Biomass: | 13080 | 1090 | 12 |

| STATION | PARAMETER | TOTAL ACCRUAL ($mg/M^2$) | ACCRUAL/DAY ($mg/M^2/day$) | NO. DAYS ACCRUAL |
|---|---|---|---|---|
| 04-Mountain View | | | | |
| | Chlorophyll a: | 51.9 | 3.1 | 17 |
| | Chlorophyll b: | 17.3 | 1.0 | 17 |
| | Chlorophyll c: | 5.4 | .3 | 17 |
| | Biomass: | 5009 | 338 | 15 |

| STATION | AUTOTROPHIC INDEX |
|---|---|
| 01-Above the discharge | 165 |
| 03-Below the discharge | 474 |
| 04-Mountain View | 109 |

The results of these analyses show a typical organically enriched stream. Chlorophyll a accrual (an estimate of net primary productivity) in the stream above the sewage discharge is high and compares to the East Gallatin River below the Bozeman sewage treatment plant discharge for similar times of year (Biological Monitoring Program Data, WQB, 1977).

The high productivity of the stream prior to further enrichment by Helena's discharge can probably be attributed to nutrient additions from East Helena's sewage discharge, irrigation returns, and contamination from livestock. Biomass accrual, another estimate of net primary productivity, is also high at the upstream site. It, too, falls within range of values measured in the East Gallatin River. The autotrophic index for the site indicates a slight organic pollution.

The situation just below the STP ditch is markedly different, even without the occurrence of an active discharge. Chlorophyll production is reduced to about half that of the upstream point (.56 times), but biomass increases

by 1.6 times. It is clear that this increase in total biomass is due to non-chlorophyllous organisms. These heterotroph populations, when supplied with an abundance of preformed organic molecules, are given the competitive advantage. The autotrophic index reflects this. The AI jumps to 474, almost a three-fold increase. This clearly shows a high degree of organic pollution. Such pollution, as pointed out earlier, must be in the form of sludge deposits, since the discharge was non-existent during the study. Some 2.5 miles of biological and chemical assimilation and decomposition of wastes result in a great deal of water quality restoration at the Mountain View site. Chlorophyll production is approaching that of above the discharge and biomass production has fallen below that of both upstream sites. Similarly, the autotrophic index has dropped to a level associated with a clean stream.

c) Periphyton

Site 01: Above the discharge, algal diversity is rather low. Oscillatoria was relatively abundant here, indicating moderate enrichment in the form of organic nutrients. Diatom diversity ($\bar{d}$), however, was relatively high. Surirella ovata, generally considered to be a clean water diatom with a high oxygen requirement, was the most abundant diatom species. The Shannon-Weaver index for this site was 2.74, and remembering that values of 3 to 4 indicate clean water, only moderate pollution is suggested. Equitability (e) for the diatom community was .39, showing relatively "even" distribution of diatom taxa.

Site 02: Periphyton collected from the sewage ditch yielded a low diversity of algal genera, the majority of these indicating heavy pollution.

This would surely be expected from a sewage effluent. *Euglena* and *Oscillatoria* were both abundant as was the diatom species *Nitzchia palea*. *N. palea*, a nitrogen heterotroph (Schoeman, 1973), is also a sign of organic pollution. Diatom Diversity ($\bar{d}$) for the site was .20, extremely low. Similarly, equitability (e) was low at .25. This can be explained by a scarcity of diatom species other than *N. palea*.

Site 03: Algal diversity just below the effluent was lowest of all the sites. Diatoms, although abundant, also lacked diversity, yielding a $\bar{d}$ of .41. The most abundant diatom was *Navicula lamii*, another nitrogen heterotroph and indicator of heavy pollution when occurring in large numbers, as it did at this site. Equitability was .19, very low due to the abundance of *N. lamii*.

Site 04: Periphyton examination at the Mountain View site shows, like the invertebrate and biomass/chlorophyll data, considerable recovery of Prickly Pear Creek. At least eight genera of non-diatom algae were found, including species indicative of a favorable though moderately enriched environment. Diatom diversity was the highest of all sites (3.24) and was within range of a clean stream. Equitability was also highest at .48. From these data, it appears that Prickly Pear Creek at this site is nutrient enriched, but not unhealthy.

## IV. Conclusions

Chlorophyll, biomass, and periphyton analyses indicate that Prickly Pear Creek is in a considerably enriched state before nutrient additions by the Helena STP discharge. This probably originates from East Helena sewage, irrigation returns, and livestock contamination. Low numbers of invertebrates above the STP outfall site are probably related to poor habitat and dewatering. Below the sewage ditch, most analyses show severe impact to the creek. However, the lack of a significant discharge apparently sustained adequate dissolved oxygen levels during the study because this site supported fair numbers of invertebrates with high oxygen requirements. At Mountain View, most of the waste has been assimilated and conditions are more favorable for aquatic life. In fact, most indications are that Prickly Pear Creek is healthier at this site than immediately above the discharge. Algal productivity is slightly lower, but has a higher diversity, the autotrophic index is substantially lower, and the standing crop of macroinvertebrates is three times as high as the upstream site. The higher invertebrate productivity, though, is probably at least partially due to a more favorable substrate at Mountain View. Despite the great recovery, the stream can still be considered eutrophic.

## V. Recommendations

A comprehensive early spring or fall sampling program should be undertaken at some time to determine maximum impact from the effluent. Also of interest would be an investigation of erosion and sedimentation problems and late season dewatering. The Mountain View station on Prickly Pear Creek has been included as a site in the southwestern Montana loop of the Water Quality Bureau's biological monitoring program. This program involves extensive chemical and biological sampling three times yearly, on a seasonal basis. When data collection

is completed in the spring of this year, interpretation of the results will hopefully shed more light on the biological status of this stream.

VI. Summary

This brief study demonstrates the complexity of factors involved in stream quality investigations. Prior to initial field work on this project, it was assumed that the degradation of water quality in lower Prickly Pear Creek was due primarily to organic pollution contributed by the Helena Sewage Treatment Plant. However, after spending several days in the area, it became apparent that dewatering and high temperatures, bank instability and sedimentation, and probably nutrient additions from irrigation return water were all related to the generally poor health of this stretch of the stream. From interpretation of the various physical and biological parameters examined for this study, it was learned that the Helena STP outfall had a very characteristic impact on the stream. There was an initial decrease in diversity and an increase in standing crop of both invertebrate and algal species just below the discharge. Chlorophyll production decreased as heterotroph populations began to thrive. With time and distance, the stream begins to recover. At Mountain View, Prickly Pear Creek has regained floral and faunal diversity and clean water indicator organisms are present. Indications of moderate enrichment, however, still exist.

This lower portion of Prickly Pear Creek has, in my opinion, the ability to become a prime trout stream, as it probably once was. This would require good stream conservation practices by upstream farmers and ranchers including sufficient flow reservations, especially during late summer. Maintenance of ripparian vegetation would also be essential. Surveillance of the STP

effluent's quality is probably sufficient at the current time. It is known that slugs of untreated wastes occasionally reach the stream when the capacity of influent exceeds the capabilities of the STP. These occurrences are not common, but are unpredictable and a solution is not readily available. These slugs probably have a great impact on the creek for at least a short way downstream causing considerable dissolved oxygen losses and a smothering of the substrate with solid materials. Whether lower Prickly Pear Creek warrants the attention evidently needed to improve its overall quality is not an easy question to answer. Most of the lower creek is bordered by private land and public access is scarce. Local landowners are the major users of the creek, be it for recreation or irrigation water. If these poeple could be convinced that their efforts at proper irrigation practices and other conservation efforts were worthwhile and could eventually provide returns for them, as well as others, in terms of improved recreation potential of the creek and aesthetics, then we would have made a large step in cleaning up Prickly Pear Creek. Their interest, or lack of it, will be the deciding factor since most of lower Prickly Pear Creek's degradation results from non-point sources, not Helena's STP effluent.

## VII. Literature Cited

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3) Montana Water Quality Standards, 1974, MDHES

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5) Schoeman, F. R. 1973 A Systematical and Ecological Study of the Diatom Flora of Lesotho with Special Reference to the Water Quality, National Institute for Water Research, Pretoria, South Africa

6) Shannon, C. E. and W. Weaver. 1964. The Mathematical Theory of Communication. University of Illinois Press, Urbana

7) Standard Methods for the Examination of Water and Wastewater, 14th Ed. 1976, APHA, AWWA, WPCF, American Public Health Association, Washington, D.C.

## VIII. Appendix

MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES WATER QUALITY BUREAU

STATION NAME PRICKLY PEAR CREEK 100 YDS ABOVE HELENA STP DISCHARGE
STATION NO. 001 SAMPLE NO. 1 MAP LOCATION
STATE COUNTY CODE 049 DRAINAGE BASIN CODE 41I
DATE COLLECTED 5-24-77 COLLECTOR INGMAN TIME COLLECTED 1300

TEMP 13.0°C DEPTH ~1 FT VELOCITY ~2.4 fps FLOW 38 cfs pH FIELD D.O.

TURB. ODOR SAMPLE METHOD SURBER SUBSTRATE RIFFLE

| | ORDER | FAMILY | GENERA | SPECIES | REL. ABUNDANCE | ABS. ABUNDANCE |
|---|---|---|---|---|---|---|
| 1 | PLECOPTERA | PTERONARCIDAE | PTERONARCELLA | | COMMON | |
| 2 | PLECOPTERA | PERLODIDAE | ISOPERLA | | COMMON | |
| 3 | PLECOPTERA | PERLODIDAE | ARCYNOPTERYX | | RARE | |
| 4 | EPHEMEROPTERA | BAETIDAE | EPHEMERELLA | | COMMON | |
| 5 | EPHEMEROPTERA | BAETIDAE | BAETIS | | COMMON | |
| 6 | TRICHOPTERA | HYDROPSYCHIDAE | HYDROPSYCHE | | RARE | |
| 7 | TRICHOPTERA | PSYCHOMYIIDAE | ——— | | RARE | |
| 8 | DIPTERA | CHIRONOMIDAE | ——— | | RARE | |
| 9 | DIPTERA | RHAGIONIDAE | ATHERIX | | COMMON | |
| 10 | HEMIPTERA | CORIXIDAE | TRICHOCORIXA | | COMMON | |
| 11 | COLEOPTERA | DYTISCIDAE | ——— | | RARE | |
| 12 | COLEOPTERA | DYTISCIDAE | ——— | (DIFF. SPP.) | COMMON | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |

ADDITIONAL REMARKS QUALITATIVE SAMPLE

ADDITIONAL SAMPLES TAKEN

EXAMINED BY INGMAN DATE COMPLETED 6-9-77

STATION NAME PRICKLY PEAR CREEK 100 YDS. ABOVE HELENA STP EFFLUENT DISCHARGE
STATION NO 001 SAMPLE NO. 2 MAP LOCATION
STATE MONT COUNTY CODE 049 DRAINAGE BASIN CODE 41I
DATE COLLECTED 5-24-77 COLLECTOR INGMAN TIME COLLECTED 1300

TEMP 13.0°C DEPTH ~1 FT. VELOCITY ~2.4 fs FLOW 38 cfs pH FIELD D.O.

TURB. ODOR SAMPLE METHOD SURBER SUBSTRATE RIFFLE

| | ORDER | FAMILY | GENERA | SPECIES | REL. ABUNDANCE | ABS. ABUNDANCE |
|---|---|---|---|---|---|---|
| 1 | PLECOPTERA | PTERONARCIDAE | PTERONARCELLA | | | 1 |
| 2 | PLECOPTERA | PERLODIDAE | ISOPERLA | | | 5 |
| 3 | PLECOPTERA | PERLODIDAE | ARCYNOPTERYX | | | 2 |
| 4 | EPHEMEROPTERA | BAETIDAE | EPHEMERELLA | | | 9 |
| 5 | EPHEMEROPTERA | BAETIDAE | BAETIS | | | 3 |
| 6 | TRICHOPTERA | PSYCHOMYIIDAE | ——— | | | 4 |
| 7 | DIPTERA | RHAGIONIDAE | ATHERIX | | | 1 |
| 8 | DIPTERA | CHIRONOMIDAE | | | | 1 |
| 9 | HEMIPTERA | CORIXIDAE | TRICHOCORIXA | | | 1 |
| 10 | GASTROPODA | ——— | ——— | | | 1 |
| 11 | DIPTERA | ? | ——— | | | 1 |
| 12 | DIPTERA | ? | ——— | | | 1 |
| 13 | | | | | | |
| 14 | | | | | | 30/3 SQ.FT. |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |

ADDITIONAL REMARKS QUANTITATIVE COLLECTION. COMPOSITE OF THREE ONE SQUARE FOOT SURBER SAMPLES (3 SQ. FT.)

ADDITIONAL SAMPLES TAKEN

EXAMINED BY INGMAN DATE COMPLETED 6-9-77

STATION NAME PRICKLY PEAR BELOW HELENA STP DISCHARGE
STATION NO. 003 SAMPLE NO. 1 MAP LOCATION
STATE MONT COUNTY CODE 049 DRAINAGE BASIN CODE 41I
DATE COLLECTED 6-9-77 COLLECTOR INGMAN TIME COLLECTED 1030

TEMP 16.5°C DEPTH <1 FT VELOCITY FLOW 15-17 cfs pH FIELD D.O.

TURB. ODOR SAMPLE METHOD SURBER SUBSTRATE COARSE SAND

| | ORDER | FAMILY | GENERA | SPECIES | REL. ABUNDANCE | ABS. ABUNDANCE |
|---|---|---|---|---|---|---|
| 1 | TRICHOPTERA | HYDROPSYCHIDAE | HYDROPSYCHE | | | 6 |
| 2 | TRICHOPTERA | BRACHYCENTRIDAE | BRACHYCENTRUS | | | 5 |
| 3 | TRICHOPTERA | HYDROPSYCHIDAE | CHEUMATOPSYCHE | | | 1 |
| 4 | TRICHOPTERA | LEPTOCERIDAE | ——— | | | 3 |
| 5 | PLECOPTERA | PTERONARCIDAE | PTERONARCELLA | | | 1 |
| 6 | PLECOPTERA | PERLODIDAE | ISOPERLA | | | 16 |
| 7 | EPHEMEROPTERA | BAETIDAE | EPHEMERELLA | | | 10 |
| 8 | DIPTERA | RHAGIONIDAE | ATHERIX | | | 3 |
| 9 | DIPTERA | CHIRONOMIDAE | ——— | | | 10 |
| 10 | DIPTERA | SYRPHIDAE | CHRYSOGASTER | | | 2 |
| 11 | COLEOPTERA | ? | ——— | | | 1 |
| 12 | | | | | | |
| 13 | | | | | | 58/3 SQ. FT. |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |

ADDITIONAL REMARKS QUANTITATIVE COLLECTION

ADDITIONAL SAMPLES TAKEN

EXAMINED BY INGMAN DATE COMPLETED 6-13-77

STATION NAME PRICKLY PEAR AT MTN. VIEW
STATION NO. 004 SAMPLE NO. 1 MAP LOCATION
STATE MT COUNTY CODE DRAINAGE BASIN CODE
DATE COLLECTED 6-8-77 COLLECTOR INGMAN TIME COLLECTED 1500

TEMP 22°C DEPTH <1 FT VELOCITY FLOW ~15 CFS pH FIELD D.O.

TURB. ODOR SAMPLE METHOD SURBER SUBSTRATE COMBINATION FAST & SLOW RIFFLE

| | ORDER | FAMILY | GENERA | SPECIES | REL. ABUNDANCE | ABS. ABUNDANCE |
|---|---|---|---|---|---|---|
| 1 | DIPTERA | TIPULIDAE | TIPULA | | | 2 |
| 2 | DIPTERA | TIPULIDAE | HEXATOMA | | | 1 |
| 3 | DIPTERA | SIMULIIDAE | SIMULIUM | | | 11 |
| 4 | DIPTERA | CHIRONOMIDAE | ——— | | | 21 |
| 5 | EPHEMEROPTERA | BAETIDAE | EPHEMERELLA | | | 4 |
| 6 | EPHEMEROPTERA | BAETIDAE | BAETIS | | | 4 |
| 7 | EPHEMEROPTERA | BAETIDAE | EPHEMERELLA | (DIFF. SPP.) | | 1 |
| 8 | PLECOPTERA | PERLODIDAE | ISOPERLA | | | 6 |
| 9 | TRICHOPTERA | HYDROPSYCHIDAE | HYDROPSYCHE | | | 48 |
| 10 | TRICHOPTERA | BRACHYCENTRIDAE | BRACHYCENTRUS | | | 7 |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | 105/3 SQ. FT. |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |

ADDITIONAL REMARKS QUANTITATIVE COLLECTION

ADDITIONAL SAMPLES TAKEN

EXAMINED BY INGMAN DATE COMPLETED 6-9-77

## Raw Data - Chlorophyll and Biomass Analyses

| Station | Parameter | Total Accrual ($mg/M^2$) | No. Days Accrual | Accrual/Day($mg/M^2$/day) |
|---|---|---|---|---|
| Site 001 | Chlor. A | 64 | 13 | 4.9 |
| | | 48 | | 3.7 |
| | | 53 | | 4.1 |
| | | 48 | | 3.7 |
| | | Average 53 | | Average 4.1 |
| | Chlor. B | 10.5 | 13 | .8 |
| | | 7.6 | | .6 |
| | | 7.5 | | .6 |
| | | 8.1 | | .6 |
| | | Average 8.4 | | Average .7 |
| | Chlor. C | 16.0 | 13 | 1.2 |
| | | 10.4 | | .8 |
| | | 13.0 | | 1.0 |
| | | 10.0 | | .8 |
| | | Average 12.4 | | Average 1.0 |
| | Biomass | 8190 | 13 | 630 |
| | | 9360 | | 720 |
| | | Average 8775 | | Average 675 |
| Site 003 | Chlor. A | 29 | 12 | 2.4 |
| | | 26 | | 2.2 |
| | | Average 28 | | Average 2.3 |
| | Chlor. B | 5.1 | 12 | .4 |
| | | 4.8 | | .4 |
| | | Average 5.0 | | Average .4 |
| | Chlor. C | 8.4 | 12 | .7 |
| | | 7.6 | | .6 |
| | | Average 8.0 | | Average .7 |
| | Biomass | 11760 | 12 | 980 |
| | | 14400 | | 1200 |
| | | Average 13080 | | Average 1090 |
| Site 004 | Chlor. A | 7.9 | 7 | 1.1 |
| | | 20.2 | 7 | 2.9 |
| | | 43.8 | 12 | 3.7 |
| | | 7.9 | 12 | .7 |
| | | 35.3 | 14 | 2.5 |
| | | 4.6 | 14 | .3 |
| | | 22.8 | 16 | 1.4 |
| | | 9.4 | 16 | .6 |
| | | 28.2 | 19 | 1.5 |
| | | 74.4 | 21 | 3.5 |
| | | 83.6 | 21 | 4.0 |
| | | 95.9 | 26 | 3.7 |
| | | 165.0 | 26 | 6.3 |
| | | 128.0 | 26 | 4.9 |
| | | Average 51.9 | Average 16.9 | Average 3.1 |

Raw Data - Chlorophyll and Biomass Analyses (continued)

| Station | Parameter | Total Accrual (mg/M$^2$) | No. Days Accrual | Accrual/Day(mg/M$^2$/day) |
|---|---|---|---|---|
| Site 004 | Chlor. B | .3 | 7 | .0 |
| | | 1.8 | 7 | .3 |
| | | 11.5 | 12 | 1.0 |
| | | 1.5 | 12 | .1 |
| | | 12.7 | 14 | .9 |
| | | 1.3 | 14 | .1 |
| | | 6.8 | 16 | .4 |
| | | 2.8 | 16 | .17 |
| | | 10.0 | 19 | .5 |
| | | 25.4 | 21 | 1.2 |
| | | 30.8 | 21 | 1.5 |
| | | 35.3 | 26 | 1.4 |
| | | 59.9 | 26 | 2.3 |
| | | 42.0 | 26 | 1.6 |
| | | Average 17.3 | Average 16.9 | Average 1.0 |
| | Chlor. C | 7.1 | 7 | 1.0 |
| | | 7.0 | 7 | 1.0 |
| | | 5.8 | 12 | .5 |
| | | 2.3 | 12 | .2 |
| | | 8.4 | 14 | .6 |
| | | 1.2 | 14 | .1 |
| | | 3.6 | 16 | .2 |
| | | 2.2 | 16 | .1 |
| | | 4.2 | 19 | .2 |
| | | 1.9 | 21 | .1 |
| | | 2.1 | 21 | .1 |
| | | 2.9 | 26 | .1 |
| | | 15.1 | 26 | .6 |
| | | 12.3 | 26 | .5 |
| | | Average 5.4 | Average 16.9 | Average .3 |
| | Biomass | 6053 | 7 | 865 |
| | | 5120 | 7 | 731 |
| | | 4426 | 12 | 369 |
| | | 12667 | 12 | 1056 |
| | | 1227 | 14 | 88 |
| | | 1413 | 14 | 101 |
| | | 7467 | 16 | 467 |
| | | 5333 | 16 | 333 |
| | | 6160 | 19 | 324 |
| | | 7573 | 19 | 399 |
| | | 1253 | 21 | 60 |
| | | 1413 | 21 | 67 |
| | | Average 5009 | Average 14.8 | Average 338 |

## Formulae

### Shannon-Weaver Diversity Index ($\bar{d}$) and Equitability (e)

Community diversity is calculated, as recommended by EPA (1973) with the following formula:

$$\bar{d} \text{ (mean diversity)} = \frac{C}{N} \left(N \log_{10} N - {}_{ni} \log_{10} ni\right)$$

where C - 3.321928, N - total number of individuals, and ni = total number of individuals in the ith species.

There are two components of species; diversity, namely richness of species and distribution of individuals among the species. Richness of species, taken by itself, is not an accurate estimate of degree of pollution. A stream may have a high number of taxa present, but the majority of organisms may be represented by one or two species. This indicates impact in one form or another. The diversity component due to distribution of individuals among the species, equitability, is computed as follows:

$$e = \frac{S'}{S}$$

where S = number of taxa in the sample

and S' = number of taxa expected in the community if it conforms to the frequently observed distribution in a clean stream in which there are few relatively abundant species and increasing numbers of species represented by only a few individuals. S' is taken from a table of such expected value.

## Autotrophic Index

The formula for calculating the autotrophic index (AI) is:

$$AI = \frac{mg/m^2 \text{ biomass}}{mg/m^2 \text{ chlorophyll } \underline{a}}$$

# Office Memorandum

STATE DEPARTMENT OF HEALTH
AND ENVIRONMENTAL SCIENCES

TO : GARY INGMAN

DATE: JUNE 28, 1977

FROM : LOREN BAHLS LB

SUBJECT : PRICKLY PEAR CREEK PERIPHYTON ANALYSES

Attached are the results of my analyses of periphyton samples from Prickly Pear Creek and the Helena STP effluent.

Representative subsamples were taken from the raw periphyton samples, prepared as wet mounts, and scanned under low power to estimate the abundance of algal genera relative to diatoms (Class Bacillariophyceae, Division Chrysophyta) and to one another. The results are presented below in Table 1.

Table 1. Abundance of algal genera relative to diatoms and to one another.

| Genus | Division | 001 | 002 | 003 | 004 |
|---|---|---|---|---|---|
| Audouinella | Rhodophyta | | | | Very Common |
| *Bacillariophyceae | Chrysophyta | Abundant | Very Abundant | Very Abundant | Abundant |
| Cladophora | Chlorophyta | | | | Common |
| Enteromorpha | Chlorophyta | | | | Present |
| Euglena | Euglenophyta | | Abundant | | |
| Oscillatoria | Cyanophyta | Common | Abundant | | Common |
| Phormidium sp. #1 | Cyanophyta | Abundant | | | |
| Phormidium sp. #2 | Cyanophyta | | | Common | Common |
| Stigeoclonium | Chlorophyta | | | | Abundant |
| Tribonema | Chrysophyta | | | | Common |
| Ulothrix | Chlorophyta | | | | Present |

*The class of the division Chrysophyta that includes the diatoms.

The blue-green genus Oscillatoria, and especially the euglenoid alga Euglena, indicate waters heavily polluted with organic matter when they are present in abundance, as they were at Station 002. Non-diatom algal diversity was low below the effluent, as it was above; however, at Station 004, there were no less than eight non-diatom genera, which, on interpreting their ecological preferences, indicate a favorable yet moderately enriched environment for algal growth. Stigeoclonium especially is a good indicator of eutrophic conditions and considerable algal productivity.

The raw samples were then treated and permanent mounts prepared for the diatom proportional counts. These were performed as per the procedure outlined in EPA (1973) except that more frustules (between 300 and 400) were counted. The completed tally forms are attached.

Table 2 below summarizes some of the significant features of the diatom communities at the four stations, namely, the percent relative abundances (PRA) of the major taxa, the number of taxa scanned and counted, Shannon-Weaver diversity ($\bar{d}$), and equitability ($e$).

(Continued)

Gary Ingman
Page 2
June 28, 1977

Table 2. Summary of diatom community parameters.

| | 001 | 002 | 003 | 004 |
|---|---|---|---|---|
| PRA Surirella ovata | 52.8 | | 0.9 | 7.8 |
| PRA Nitzschia palea | 7.9 | 97.4 | 2.0 | 24.0 |
| PRA Navicula lamii | 2.9 | | 95.1 | 31.2 |
| Total Taxa | 39 | 11 | 29 | 47 |
| Taxa Counted | 23 | 4 | 8 | 28 |
| $\bar{d}$ | 2.741 | 0.203 | 0.405 | 3.237 |
| e | 0.39 | 0.25 | 0.19 | 0.48 |

To aid you in interpreting these results, I've attached some ecological observations on the three major taxa by Schoeman (1973) and some material from EPA (1973) on interpretation of $\bar{d}$ and e values.

Surirella ovata is generally considered by other sources as a clean water diatom, however, it is rarely encountered in such large numbers as were present at Station 001. Nitzschia palea and Navicula lamii are both nitrogen heterotrophs but apparently N. lamii cannot compete with N. palea under conditions of heavy organic pollution. As you can see, both diatom and non-diatom algal diversity were greater below the effluent at Station 004. I have noted this occurring on the East Gallatin below the Bozeman STP and it is apparently due to a reduction in competition resulting from an increased supply of biologically available nutrients. However, there was a striking depression in diatom diversity immediately below the effluent at Station 003.

## REFERENCES

Environmental Protection Agency. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Cincinnati.

Schoeman, F. R. 1973. A Systematical and Ecological Study of the Diatom Flora of Lesotho with Special Reference to the Water Quality. National Institute for Water Research, Pretoria, South Africa.

DIATOM PROPORTIONAL COUNT

Sample No. 0292A . Notebook No. 5 . Page No. 54 .

Major or Sub-Major Basin Missouri-Smith . Minor Basin 41I .

Water and Location Prickly Pear Creek, 100 yds. above HSTP effluent .

Community Periphyton . Substrate natural .

Date 5-24-77 . Collector/Agency Ingman / WQB . Project HSTP .

| TAXON | COORDINATES (WILD M12) | NUMBER | PERCENT RELATIVE ABUNDANCE |
|---|---|---|---|
| Surirella ovata | | 181 | 52.8 |
| Nitzschia palea | | 27 | 7.9 |
| Achnanthes lanceolata | | ~~\|\|\|\|~~ \|\|\| | 2.3 |
| A. minutissima | | 25 | 7.3 |
| Gomphonema parvulum | | 10 | 2.9 |
| Fragilaria vaucheriae | | 9 | 2.6 |
| Navicula avensis | | \|\| | 0.6 |
| N. cincta var. rostrata | | 18 | 5.2 |
| *N. lanceolata (18.95x 103.5) | | 20 | 5.8 |
| Pinnularia sp. (18.95x 103.5) | | | t |
| Navicula lamii | | ~~\|\|\|\|~~ ~~\|\|\|\|~~ | 2.9 |
| Synedra rumpens (19.0x 103.5) | | / | 0.3 |
| Nitzschia frustulum var. subsalina | | / | 0.3 |
| Cymbella angustata | | | t |
| Cymbella angustata (19.65x103.7) | | | t |
| Ch[illegible]ella (iowensis?) | | \|\| | 0.6 |
| Gomphonema olivaceum | | / | 0.3 |
| Nitzschia linearis | | \|\| | 0.6 |
| Pinnularia sp. (18.5x102.9)(17.8x | | 102.7) / | 0.3 |
| Gomphonema truncatum (17.9x | | 103.4) | t |
| Cymatopleura solea | | | t |
| Fragilaria capucina (17.8x 103.1) | | | t |
| Cymbella sp. (17.5x 102.7) | | | t |
| Amphora perpusilla | | | t |
| Navicula accomoda | | (17.9x 102.4) | t |
| Nitzschia hungarica (17.7x102.4) | | | t |
| Achnanthes linearis | | | t |
| Cymbella minuta | | \|\| | 0.6 |
| Synedra ulna | | | t |
| Cymbella cistula (21.0x101.4) | | | t |

DIATOM PROPORTIONAL COUNT

Sample No. 0293A . Notebook No. 5 . Page No. 55 .
Major or Sub-Major Basin Missouri - Smith . Minor Basin 41 I .
Water and Location Helena STP effluent near Prickly Pear Cr. .
Community Periphyton . Substrate natural .
Date 5-27-77 . Collector/Agency Ingman /WQB . Project HSTP .

| TAXON | COORDINATES (WILD M12) | NUMBER | PERCENT RELATIVE ABUNDANCE |
|---|---|---|---|
| Nitzschia palea | | 296 | 97.4 |
| Navicula cryptocephala var. veneta | | | t |
| N. accomoda (19.7 x 102.4) | | 6 | 2.0 |
| Melosira (granulata?) (20.3 x 105.1) | | | t |
| Hantzschia amphioxys (broken) | | | t |
| Achnanthes minutissima | | 1 | 0.3 |
| Epithemia sp (20.8 x 107.7) | | | t |
| Synedra ulna | | | t |
| Neidium sp. (14.5 x 108.9) | | | t |
| Denticula elegans (12.45 x 108.5) | | | t |
| Asterionella formosa (16.0 x 106.6) | | 1 | 0.3 |

DIATOM PROPORTIONAL COUNT

Sample No. 0294A. Notebook No. 5. Page No. 55.
Major or Sub-Major Basin Missouri - Smith. Minor Basin 41I.
Water and Location Prickly Pear Creek 100 yds. below HSTP effluent.
Community Periphyton. Substrate natural.
Date 5-27-77. Collector/Agency Ingman / WQB. Project HSTP.

| TAXON | COORDINATES (WILD M12) | NUMBER | PERCENT RELATIVE ABUNDANCE |
|---|---|---|---|
| Cymatopleura solea | | | t |
| Surirella (iowensis ?)(7.2 x 105.1) | | | t |
| S. ovata | | 3 | 0.9 |
| Gomphonema parvulum | | | t |
| Nitzschia palea | | 7 | 2.0 |
| Surirella angustata | | | t |
| Navicula lanceolata | | | t |
| N. cincta var. rostrata | | 1 | 0.3 |
| N. lamii | | 327 | 95.1 |
| Cymbella minuta | | 2 | 0.6 |
| Achnanthes minutissima | | | t |
| Nitzschia linearis | | | t |
| Navicula accomoda | | 2 | 0.6 |
| Nitzschia frustulum | | 1 | 0.3 |
| Pinnularia sp. (8.9 x 105.05) | | | t |
| Achnanthes lanceolata | | | t |
| Cymbella sinuata | | | t |
| Fragilaria vaucheriae | | | t |
| Stephanodiscus minutus | | | t |
| Synedra ulna | | | t |
| Cocconeis placentula | | | t |
| Nitzschia sinuata | | | t |
| Navicula (minima ?) | | | t |
| Cymbella cistula (12.7 x 105.1) | | | t |
| Nitzschia hungarica | | | t |
| Cymbella sp. (15.6 x 105.1) | | | t |
| Amphora ovalis var. affinis (16.4 x 105.1) | | | t |
| Denticula sp. (19.5 x 105.15) | | | t |
| Navicula arvensis | | 1 | 0.3 |

# DIATOM PROPORTIONAL COUNT

Sample No. 0309A . Notebook No. 5 . Page No. 64 .
Major or Sub-Major Basin Missouri - Smith . Minor Basin 41I .
Water and Location Prickly Pear Creek @ Mountain View School .
Community Periphyton . Substrate natural .
Date 6-1-77 . Collector/Agency Ingman / WQB . Project HSTP .

| TAXON | COORDINATES (WILD M12) | NUMBER | PERCENT RELATIVE ABUNDANCE |
|---|---|---|---|
| Cymatopleura solea | | | t |
| Meridion circulare | | | t |
| Diatoma vulgare | | | t |
| Pinnularia borealis | (19.9 x 100.1) | | t |
| P. sp | | | t |
| Fragilaria vaucheriae | | 21 | 5.8 |
| Cymbella minuta | | 4 | 1.1 |
| Surirella ovata | | 28 | 7.8 |
| S. (iowensis?) | | /// | 0.8 |
| Gomphonema parvulum | | 4 | 1.1 |
| Synedra ulna | | | t |
| Cocconeis placentula | | | t |
| Surirella angustata | | // | 0.6 |
| Nitzschia palea | | 86 | 24.0 |
| N. linearis | | 1 | 0.3 |
| Navicula cuspidata | (21.0 x 99.8) | | t |
| N. lanceolata | | 13 | 3.6 |
| N. minima | | 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 / | 10.0 |
| Nitzschia dissipata | | /// | 0.8 |
| Epithemia sp. | (20.2 x 99.9) | | t |
| Gyrosigma acuminatum | (19.85 x 100.1) | | t |
| Navicula heufleri var. leptocephala | (19.7 x 97.3) | | t |
| N. lanii | | 112 | 31.2 |
| N. arvensis | | 𝍸 | 1.4 |
| N. accomoda | | 𝍸 / | 1.7 |
| N. secreta var. apiculata | | / | 0.3 |
| Nitzschia frustulum | | 𝍸 //// | 2.5 |
| N. amphibia | | // | 0.6 |
| Cyclotella meneghiniana | | | t |
| Nitzschia acicularis | | | t |

the use of the scanning electron microscope may help to solve some of the difficulties.

In the Lesotho material a complete series of specimens ranging in length from (3.8) 4.7-16.0 μm and in width from 1.5-4.0 μm were seen. The valvar shape was very variable, some specimens having well rounded ends and others protracted ends which may be broadly rounded or rostrate.

This small diatom species is widely distributed throughout the Lesotho area, occurring in 39% of the samples. It was present in many different habitats but appeared to favour the trickling or running waters of streams and rivers. In three samples it was the dominant species and in others the subdominant one, e.g. 10 (55.0%), C100 (17.1%), C109 (29.4%), C110 (57.2%), C119 (16.3%), C127 (41.8%), C136 (32.1%), C138 (13.2%), D47 (17.9%), D48 (20.9%). In the samples listed above it was accompanied by large frequencies of nitrogen heterotrophic *Nitzschia* species and/or nitrogen heterotrophic *Navicula* species, viz. *N. muralis* and *N. perparva*. These samples further contained no, or very small numbers of oxygen indicating *Achnanthes* and *Fragilaria* species (indicators of oligotrophic conditions). Due to the flowing motion of the waters in which these samples were collected, a high percentage oxygen saturation can be expected but due to the eutrophic conditions, the oxygen indicator species were lacking. These results suggest that *N. Lamii* favours waters enriched with nitrogenous organic compounds, but is probably unable to compete with nitrogen heterotrophic *Nitzschiae* at high concentrations of organic nitrogenous compounds. The measured pH values of the samples in question (except C138 - not available) were all above pH 8.0 indicating its preference for alkaline waters. The pH values of these samples, deduced from the relative frequencies of the species in the associations, range from about 7.8-8.4.
Figures: Pl. 5, figs. 158-166, 171.

e.g. N. hychia pale

*Navicula lanceolata* (AGARDH) KÜTZING (1844 : 94, Pl. 28, fig. 38, Pl. 30, fig. 48; cf. GRUNOW in CLEVE and GRUNOW 1880 : 35, GRUNOW in VAN HEURCK 1880-1885 : 88, Pl. 8, fig. 16; A. SCHMIDT in A. SCHMIDT Atlas, Pl. 47, fig. 49; CLEVE 1895 : 21; VAN HEURCK 1896 : 186, Pl. 3, fig. 139; PERAGALLO and PERAGALLO 1897-1908 : 100, Pl. 13, fig. 2; HUSTEDT 1930 : 305, fig. 540 = *Cymbella lanceolata* AGARDH (?) = *Frustulia lanceolata* KÜTZING, cf. KÜTZING 1844 : l.c.).

pores in 10 µm. These specimens were 17-29 µm long, 3.5-4.1 µm wide with 13-16.5 carinal pores in 10 µm (cf. Pl. 7, figs. 224-226) and undoubtedly belong to this species, the carinal pores being of the elongated type which is typical of *N. palea*.

In another Lesotho sample (C165) some rather slender forms of this species were observed (31-36 µm long, 2.6 µm wide and 12-13 carinal pores in 10 µm). On morphological grounds it is impossible to separate them from the type. CHOLNOKY (personal communication) has observed similar slender forms in material from the Kenya mountain region.

The *N. palea* population of sample J7, collected from a streampool near 'Mamathe, displayed a fairly wide variation in valvar length. These specimens were 12-40 µm long and 3.5-4 µm wide with 11-12 carinal pores in 10 µm. The smaller specimens of this series (12-17 µm long) were, therefore, short and broad. CHOLNOKY-PFANNKUCHE (1970 : in press) has observed similar small specimens (6.5-13.5 µm long and 4 µm wide) in four year old cultures of *N. palea*.

CHOLNOKY (1966b : 205-206; 1968c : 239, 469-470, 628; 1970c : 30) has discussed the autecology of this species in quite some detail and states that it inhabits eutrophic, oxygen-rich, alkaline freshwaters. It has a pH optimum at 8.4 (CHOLNOKY 1968c : 415) and is an obligate, nitrogen heterotrophic species. EVANS (1958a : 161) has established that, in drying experiments, *N. palea* is able to survive severe and prolonged drought. There is no doubt that *N. palea*, when occurring in large numbers, is a good indicator of eutrophic conditions. BLUM (1957 : 398) states that it occurred abundantly in the polluted waters of the Saline River (sewage and industrial wastes). FJERDINGSTAD (1964 : 109) has observed *N. palea* and *N. thermalis* on trickling filters in Danish purification plants. Similarly CHOLNOKY (1968c : Chapter 22) has observed it in South African sewage works and sewage polluted rivers. In his study of the diatom flora of the Werra River (Germany), SCHEELE (1956 : 446) remarks that *Melosira varians* and *N. palea* are mesosaprobic species that serve as indicators of polluted waters. BACKHAUS (1968b : 311) has also reported *N. palea* to be abundant in the alpha-mesosaprobic "Abwasserzonen" of the tributaries of the upper Danube. BUTCHER (1949), KOLKWITZ (1950 : 10), SRÁMEK-HUSEK (1956 : 381), and LIEBMANN (1962 : 332-333) all regard *N. palea* to be an alpha-mesosaprobic species.

In Lesotho and its surroundings, *N. palea* was one of the most common species, occurring in 79% of the samples, and often being the

Dimensions: 38-80 µm long, 21-37 µm wide and 40-53 canals in 100 µm.

CHOLNOKY (1968c : 246) maintains that *S. ovalis* is not a brackish water species nor a mesohalobe as has been stated by a number of authors (cf. HUSTEDT 1930 : 441; 1957 : 362; FOGED 1964 : 149). It is a freshwater diatom which inhabits strongly alkaline water and is able to tolerate fluctuations in osmotic pressure very well. For this reason it is found in brackish water as well (CHOLNOKY l.c.). *S. ovalis* has a pH optimum of about 8.5 (or slightly higher) and is unable to tolerate pH fluctuations.

In the Lesotho area, this species was found in eight samples (mostly single specimens). The highest relative density was recorded in sample C115 (2.4%). This sample was dominated by *Nitzschia frustulum* (36.0%), a brackish water diatom with a pH optimum of about 8.0.
Samples: 65, C85, C115, C117, C120, D19, P162, P822.

*Surirella ovata* KÜTZING (1844 : 62, Pl. 7, figs. 1-4; cf. SMITH 1853 : 33, Pl. 9, fig. 70; VAN HEURCK Atlas 1880-1885, Pl. 73, figs. 5-7; HUSTEDT 1930 : 442, figs. 863, 864; LUND 1946 : 104, figs. 18 K-DD).

This common European species, "Überall verbreitet und sehr häufig" (cf. HUSTEDT 1930 : 445), was very rare in Lesotho. A number of small specimens were observed in one sample from the Leribe district. LUND (l.c.) found that the British soil specimens he examined, had 60-90 canals in 100 µm and 20-30 transapical striae in 10 µm.
Dimensions: 12.5-19 µm long, 7.5-8 µm wide and 75-85 canals in 100 µm.

*S. ovata* is a freshwater species that can tolerate slight fluctuations in osmotic pressure rather well and may, therefore, also be common in certain brackish waters (CHOLNOKY 1968c : 246). Its pH optimum lies between 7.5 and 8.0 (CHOLNOKY 1968c : 422). Alkaliphilous according to SCHEELE (1956 : 445), HUSTEDT (1957 : 363), FOGED (1964 : 149) and BACKHAUS (1968b : 312). SCHEELE (1952 : 373) has stated that, "Gegen Sauerstoffmangel und Verschmutzung scheint die Art besonders resistent zu sein". This statement (with regard to oxygen) is in direct conflict with CHOLNOKY's (1968c : 471) observations, viz. that *S. angusta* and *S. ovata* appear to have "einen recht hohen Sauerstoffbedarf".
Sample: P500.

"high oxygen requirement"